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Effect of Sand mining on Ground Water in Kano River Catchment

Aliyu Baba Nabegu
Department of Geography
Kano University of Science and Technology, Wudil
Email of the corresponding author:prepra@live.com

Abstract
This study assesses the impact of sand mining on wells situated within 1km radius of Wudil river channel. The channel was divided into three sites consisting of (i) Upstream of the active mining (ii) Active mining area (iii) Downstream of active mining area. The upstream of the mining site was assumed to be unaffected by sand mining and was thus considered as reference site. The mining site was an area of active sand mining. The downstream area is the area with no active mining but, within the impact of the mining activity. In order to determine the impact of sand mining, an inventory of bore holes, wash bore and open wells within one kilometer radius in the three sites was taken and fifty water samples at each of the three sites at various flow levels was taken for nephelometric turbidity analysis. To determine historic changes on the wells such as age of wells and well failure rate, interview was conducted with 25 respondents who use wells for irrigation, domestic and other purposes in each of the three sites. The officer responsible for the Wudil regional water scheme that operates 90% of all boreholes in the area was also interviewed. The results shows a marked variation in the location, failure rate, longevity and levels of turbidity in the wells between the sites suggesting that sand mining has impacted negatively on the ground water quality and quantity. The study recommends a basin scale study and simulation study in order to garner more information that will allow for sufficient understanding that is required for the regulation of mining activity.
Key words: water quality, contamination, aquifer, water resources, irrigation**,** stream ecosystem

1. Introduction

Rapid increase in population of 3% per anum, unprecedented urbanization estimated at 40% and rising economic growth has led to increased and continued demand for river sand as material for housing and general infrastructure construction in Kano region and the main source is from river channels because they provide high quality material at low cost. River sand is particularly desirable because weak materials are eliminated by abrasion and attrition leaving durable, rounded and well-sorted materials that require less processing than many other sources (Barksdale, 1991) and are commonly located near the market or transportation routes.
However, sand mining has been shown to cause severe negative environmental impacts that are not reversible (Kondolf, 1997; Rovira, *et.al.,*2005; Rinaldi, *et.al.,*2005; Nabegu, 2012). One of the most serious and subtle but ignored negative consequence of sand mining is on ground water recharge and quality as a result of the extraction process (Herlling, 1982), because for centuries, humans have been enjoying the natural benefits provided by rivers without understanding much on the river ecosystem (Naiman 1992; Naiman and Bilby 1998), particularly alluvial channels such as Kano River (Lu *et.al.,* 2007). For instance, some of the characteristics that make sand a valuable resource also make it a very good aquifer and recharge materials. Also, sand mining within an aquifer recharge area will increase the vulnerability of the aquifer to be contaminated because it decreases the distance between the ground water table and land surface. In some cases, the excavation actually penetrates the shallow aquifers, leading a direct access to ground water (Depreeze, 2000).
In recent years there have been increased concerns for maintaining high quality groundwater supplies as a result of the recognition of the potential negative impact of sand mining since the mining operations are often located in areas favorable for developing potable groundwater. Despite this, there have been no studies on the extent of sand mining operations or of the impacts in Kano region. Yet, minimization of the negative effects of sand mining requires a detailed understanding of the nature and sources of the impacts on ground water resources (Kondolf, 1997,Rinaldi *et.al.,*2005, Rovira, *et.al.,* 2005) . The aim of this study is therefore to assess the impact of sand mining on ground water in adjourning areas of Kano River in order to garner the necessary data that will provide information for proper regulation of the activity.

2. Materials and Methods

This study was conducted between November 2011 and May 2012. Kano River at Wudil was surveyed to ascertain the number and location of active sand mining. To assess the impact of sand mining, the channel was divided into three sites based on the technique used by Brown *et.al.,* (1998) consisting of (i) Upstream of the active mining (ii) Active mining area (iii) Downstream of active mining area. The upstream of the mining site was assumed to be undisturbed and was thus considered as reference site. The mining site was an area of active sand mining. The downstream area is the area with no active mining but, within the impact of the mining activity. In order to determine the impact of sand mining, inventory of boreholes, wash bore and open wells around the three sites was conducted within a one kilometer radius. Fifty water samples in each of the three sites at various flow levels were collected for nephelometric turbidity analysis. To determine historic changes such as age of wells and rate of well failure, interview was conducted with 25 respondents who use wells for irrigation, domestic and other purposes in each of the three sites. The officer responsible for the Wudil regional water scheme, that supply water to 2.5million people based on borehole situated on the floodplain of Kano River was also interviewed.

3. Study Area

Kano River is part of the complex system of the Hadejia river basin in which three principal tributaries of Kano, Challawa and Watari streams join above Wudil to form what it referred to as the Upper Hadejia (Fig. 1). Downstream of Wudil, the basin is underlain by the Chad basin formation. Upstream, it is underlain by the Basement Complex of Precambrian rocks. The topsoil consists of mainly sandy loam covered by aeolian sand derived from wind deposits with thickness of about 5m in the upland and 10m along the lowland plains. The Basement complex consists of granite with biotite gneiss. Isolated lateritic formations which are found in abundance in the area are also found in the flood plain. Recharge of the aquifer takes place mainly from rainfall. The river has been impacted by dam and other structures along its channel. Total populations of over 2.5 million people obtain water either directly by abstraction from the channel or from tube well or borehole and wash bore for irrigation.

4. Results and Discussion

4.1 Impact of mining site on location and well types

Table 1 show that the majority of the wells 54% are located in the upstream site and the least 11%, in the mining site and 35% downstream. The wash bore are the dominant type accounting for 51.7% of all wells. They are used for irrigation on the floodplain as they are cheap to make requiring very little labor due to the high water table in the flood plain. The average depth is 1.5 meters. The tube wells account for 42.1% and are mostly used for domestic water supply with average depth of 4 meters and the boreholes make up 6.1% and are used for the municipal water supply by the Wudil regional water supply and in large institutions such as the Universities (KUST Wudil and Police academy) and industrial water production plants and commercial activities. Average depth is 25m.

The types of wells vary between the sites. The wash bore is dominant upstream 59.1% and least in the mining site 3.9%, whereas, the borehole is dominant in the mining site 54% and equally spread in the mining site 26.2% and downstream at 19.8%. The tube well is dominant downstream 62.7% and least in the mining site at 12.7%. In all the three sites only 12.9% of the wells are located 0-10meters from mining operation. Also, only 0.3 %, of the 3% of the wash bores in the mining site is located 0-10m to the mining operation.

The absence of wash bore and tube well in the mining site is due to the fact that they are the most susceptible to sand mining impact because sand mining results in the river channel turning into large and deep pit as a result of continuous excavation, consequently, the groundwater table drops. According to (Depreeze, 2000), when sand mining becomes intense, the vertical and lateral movement of water is checked and affects the recharge of groundwater and due to the drop in ground water levels, quantity and quality of water is affected negatively especially during the dry season when there is no rainfall. Interview conducted with the users of the wells indicate that in the mining site, groundwater table has been lowered up to 13 meters from 3 meters in the last twenty years. It was also observed that the ground water levels in this area stabilized at 4 meters in the rainy season (July – September) but drops to 7-9 meters in the dry season (November - June) . A further evidence of lowered water table is that all the 26 borehole located within the mining site are drilled to depths of 35 to 55 m, while the three located on KUST campus downstream are at an average 20 -30m in depth.

4.2 Impact of mining on Age of Wells

The Age of well refers to number of years a well has functioned (Thrivikumaji, 1993). Wash bore wells in mining site have an average life span of 1.3 years, downstream 4 years and upstream 9 years. Boreholes have average life span of 5, 11 and 24years in the three sites respectively. Similar pattern was exhibited by the tube well with a life span of 3.8, 5.7 and 7.2 years respectively.

The age of well illustrate the impact of sand mining on ground water and this is reflected in the rate of well failure, which is 81.1 % in the mining site compared with downstream 24% and upstream 15.7 % . Table 3 illustrates the variation in failure between well types in the different sites. Well failure is higher in wash bore wells, with 95% failure in mining site and 74% downstream and 20 % upstream. Clearly, the wash bore and tube well show higher failure rate in all three sites. This is due to the fact that, as a result of sand extraction, the riverbed loses its ability to hold water as sand takes several years for its deposition and this affects groundwater recharge especially in a chronically drought stricken areas (Deidin and Lee,1980) such as the Kano region. Secondly, as sand is extracted rapidly, groundwater evaporates fast, reducing groundwater recharge, increasing initial and premature failure of wells (Landsberg, 1982).

Deepening of the channel as a consequence of sand mining, in turn affect water table within the valley as the water table is depressed by several meters due to deepening of the channel which results in water wells drying up (Depreeze, 2000, Norsalyn and Mohd, 2012). The high rate of failure in the downstream site confirms the findings by Kondolf (1997) that the impacts in the mining sites are self propagating and will continue downstream.

4.3 Impact of mining on Ground Water Quality

Table 4 shows the mean turbidity of water collected in the three sites. Turbidity is the cloudiness or murkiness of water, which is an expression of the optical properties of water, which cause the light to be scattered and absorbed rather than transmitted in straight lines. It is therefore commonly regarded as the opposite of clarity (Wass *et al*., 1997). Turbidity impairs the suitability of the water for many purposes. Table 4 indicates that turbidity is significantly higher (*P,* 0.05) in the mining site with the mean turbidity levels three times the levels than upstream.

Downstream turbidity levels are double what are obtained upstream. High levels of mean turbidity in the mining and downstream sites is due to increased riverbed and bank erosion associated with sand mining which increases suspended solids in the water at the mining and downstream sites. Mining operation also release fine sand and small silt particles that are present in the stream. Silt particles (< 63 μm) can be transported over large distances by the river because of their small settling velocity (Kondolf,1994).

Although water turbidity does not pose a serious problem to ground water since it is unable to migrate beyond the immediate infiltration site, the continual infiltration of the turbid water does raise the potential for other sources of contaminant to migrate to the aquifer because it decreases the distance between the ground water table and land surface. In some cases, the excavation actually penetrates the shallow aquifers, leading a direct access to ground water (Depreeze, 2000).This is particularly the case with a shallow river, like the Kano River with a mean depth of 3- 4 meters. Any chemical contaminants that are allowed to enter wash water or spills in the area would have quicker access to the aquifer. Once in the ground water, a chemical substance would be free to move with the water in the aquifer.

It should also be recognized that although it does not pose a threat to the health of water users, the impact of turbidity are many and include, its being as primary agent causing biological stresses; source of introduction of abnormal volumes of organic material and nutrients and reintroduction of toxic substances uncovered by mining activities thus increasing the biological oxygen demand (BOD), which in turn reduces oxygen levels. Also it has been observed that sand mining operations reduce the buffering capacity of subsurface materials by removing the soil layer from an area. The reduction in buffering capacity makes the groundwater sensitive to pH change (Borges, *et,al,*2002) . Other impact of turbidity is discoloration of water which more than anything renders good water appear bad. For instance, a total of 2.5 million inhabitants of Gaya, Wudil, Garko, Warawa and Dawakin Kudu local government area depend on Wudil regional water supply which is based on ground water abstraction within the channel has reported significantly increased water treatment costs . KUST sachet water is unique by its brownish color due to the murky color of the borehole.

5. Conclusion

Groundwater is an important and plentiful source of clean and cheap water for irrigation, domestic and other uses in Kano region. Currently, this important source is seriously threatened due to excessive sand mining in river channels. This calls for a serious, effective and efficient regulation of sand mining. As a mitigation measure, simulation studies should be undertaken to investigate sand mining process and test various methods and strategies in order to minimize ecological effects. However, this requires long term physical observation and data collection. Also, there is an urgent need to evaluate effects of sand mining on a river basin scale, so that cumulative effects of extraction can be recognized and addressed at various levels for proper remedial measures.

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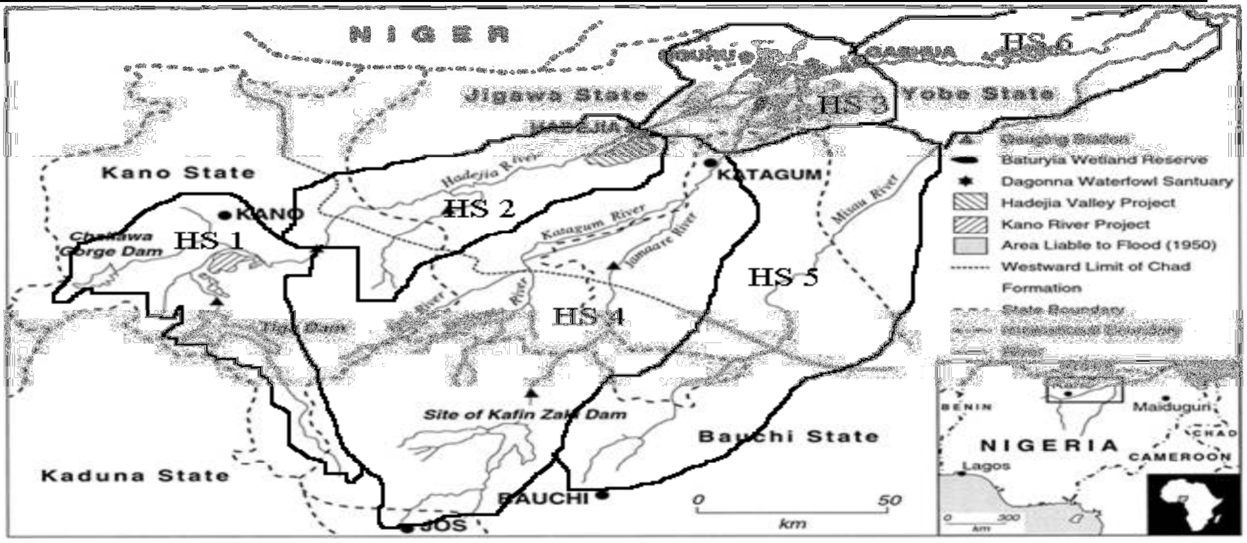

Fig.1 Kano River Basin

Table 1 Distance between Mining activity and Well failure

Particulars	Mining site	Upstream	Downstream
Total number of wells	180	892	933
Number of functional wells	34	752	709
Number of failed wells	146	140	224
Proportion of well failure	0.8111	0.1569	0.240

Table 2 Proportion of Well Failure

	Mining site			Upstream Site			Downstream Stream		
	Distance from mining site								
Types of wells	0-10m	10-50m	50-200m	0-10m	10-50m	50-200	0-10m	10-50m	50-200m
Borehole	04	20	0 8	11	33	22	07	09	18
Tube well	13	46	48	51	58	107	41	48	69
Washbore	08	14	19	70	128	412	52	96	233
Total No	25	80	75	132	119	541	100	153	320

Table 3 Variation in Failure between Well Types

Particulars	Mining site	Upstream	Downstream
Total number wash Bore	41	610	381
Number of failed wash bore	39	123	284
Number of wells not functioning	2	487	97
Proportion of wash bore failure	0.9512	0.2016	0.7454
Number of functional Tube Well	107	216	528
Number of failed Tube well	87	52	292
Number of wells not functioning	20	164	236
Proportion of Tube well failure	0.8130	0.2407	0.5530
Number of Bore hole	32	66	24
Number of failed Tube well	23	12	11
Number of wells not functioning	9	54	13

Table 4 Mean Turbidity in the three Sites (*P,* 0.05).

Site	Nephelometric turbidity units
Upstream	14.87
Mining site	39.02
Downstream	29.42